B7 (cont'd)

one of the metals in the group comprising Cr, Nb, Sn, W, Ta and other metals with similar work functions.

Please add the following claims:

B8

52. The diode of claim 1, wherein said barrier height is low enough for low forward voltage operation in the range of 0.1 to 0.3 volts.

53. The diode of claim 15, wherein said barrier potential has a magnitude that allows said diode to operate as a low forward voltage diode with a forward voltage in the range of 0.1 to 0.3 volts.

REMARKS

Objections

The examiner objected to claims 2, 3, 6, 15, 19, 20, 22 and 47-49 because of informalities/defects and the claims have been amended to incorporate the examiner's suggested changes. It should be understood that these claim amendments are only "suggested" to improve the form of the claims and they are "non-limiting". Accordingly these amendments do not limit the scope of the claims and are not being made for reasons related to patentability.

Rejections

35 U.S.C 102(b)

The examiner rejected claims 1-5, 7, 8, 14-21, 23, 24, 28 and 43-48 under 35 U.S.C. 102(b) as being anticipated by Mohammad et al. [Mohammad et al., Near-Ideal Platinum-GaN Schottky Diodes, Electronics Letters, March 14, 1996, V32,

N6, pages 598-599]. Mohammad et al. describes the fabrication and electrical characteristics of a nearly ideal Pt-GaN Schottky diode and uses this structure to estimate the effective mass m*. The author's investigation and findings were based on the expectation that electrical devices fabricated from GaN will "operate at high power levels, high temperatures and in a caustic environment." However, Mohammad does not suggest a Schottky diode with low forward voltage characteristics. One reason for this may be that GaN has conventionally been associated with high voltage/power when electrical devices are considered.

The development of a low forward voltage GaN Schottky diode is both novel and unobvious. The specification and claimed invention focuses on GaN devices whose Fermi level is unpinned and as a result, different Schottky metals with different work functions result in different barrier potentials. A low forward voltage GaN based diode is described and claimed having a forward voltage in the range of 0.1 to 0.3 volts. In applicants' GaN Schottky diodes, the barrier height at the metal to semiconductor junction varies depending on the metal used. The metals listed in the specification include Ti, Cr, Nb, Sn, W, and Ta, all of which result in an acceptably low barrier potential resulting in a lower V_f. Mohammad does not disclose, teach or suggest this lower V_f Schottky diode operation or a Schottky metal that would result in this lowered barrier potential.

Independent claims 1, 15 and 43, have been amended to further focus on these novel and unobvious differences. Claim 1 has been amended so that the surface of the n-doped GaN layer has an unpinned Fermi level and the particular Schottky metal used results in diode barrier height low enough to allow low forward voltage (V_f)

operation. Independent claim 15 was amended to so that the higher and lower doped layers are gallium nitride based and the lower doped layer has an unpinned surface potential and an electron affinity. The diode's barrier potential is approximately equal to the Schottky metal's work function minus the electron affinity and the barrier potential has a magnitude that allows the diode to operate as a low forward voltage (V_f) diode. Similarly, claim 43 has been amended so that the diode is Group III nitride based and operates as a low forward voltage diode.

Support for these amendments can be found in the claims as originally filed and in the specification and drawings as filed. Specifically, support can be found in the specification on page 7, line 18 to page 12, line 14, and in FIGs. 1-3.

Mohammad et al. does not disclose, teach or suggest these limitations and applicants respectfully submit that these claims are allowable. The remaining claims that were rejected under this section depend from the allowable independent claims and are also allowable.

35 U.S.C 103(a)

The examiner rejected claims 6, 22 and 49 under 35 U.S.C. 103(a) as being unpatentable over Mohammad et al. as applied to claims 1-5, 7, 8, 14-21, 23, 24, 28 and 43-48 above, in view of Binari et al. [Binari et al., Electronic Characterisation of Ti Schottky Barriers on N-type GaN, Electronics Letters, March 14, 1996, V32, N6, pages 598-599]. The claims rejected under this section depend from the allowable amended independent claims and are also allowable.

Regarding the contents of the Binari article, only an investigation of a Ti-GaN Schottky diode is reported.

Accordingly, claims 6, 22 and 49 have been amended to remove the reference to Ti. Binari does not disclose, teach or suggest the low forward voltage GaN based diodes. Instead, it focuses on the measurement of the Schottky barrier height of Ti on n-type GaN, which was measured by capacitance-voltage and current-voltage techniques. Binari claims that this was the first measure of the Schottky barrier height on GaN for a metal other than Au. Binari does not disclose, teach or suggest a low forward voltage diode using the metals and semiconductor materials disclosed and claimed in the present application.

Added Claims

Claims 52 and 53 have been added to more fully claim the range of voltages (0.1 to 0.3 volts) for low forward voltage operation of the claimed diodes. Support for these claims can be found in the specification as filed on page 4, lines 12-14.

All of the claims in the application are now believed to be in proper form for allowance, and a Notice of Allowance is respectfully requested.

Respectfully submitted,

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Jaye G. Heybl
Attorney for Applicants
Registration No. 42,661

KOPPEL JACOBS PATRICK & HEYBL
555 St. Charles Drive, Suite #107
Thousand Oaks, CA 91360
(805)373-0060

VERSION WITH MARKINGS TO SHOW CHANGES MADE

Claims

1. (Amended) A Group III nitride based diode, comprising:

an n+ doped GaN layer;

an n- doped GaN layer on said n+ GaN layer, the surface of said n- doped GaN layer having an unpinned Fermi level; and

a Schottky metal layer on said n- doped GaN layer having a work function, said n- GaN layer forming a junction with said Schottky metal, said junction having a barrier potential energy level that is dependent upon the work function of said Schottky metal, said barrier height low enough to allow low forward voltage operation of said diode.

2. (Amended) The diode of claim 1, wherein said barrier potential [varies directly with] depends directly on said Schottky metal work function.

3. (Amended) The diode of claim 1, wherein said n- doped GaN layer has an electron affinity, said barrier potential being [generally] approximately equal to said Schottky metal work function minus said electron affinity.

6. (Amended) The diode of claim 1, wherein said Schottky metal is one of the metals from the group comprising [Ti,] Cr, Nb, Sn, W, and Ta [and Ge].

15. (Amended) A diode, comprising:

a layer of highly doped gallium nitride semiconductor

material [having an unpinned surface potential];

a layer of lower doped gallium nitride semiconductor material adjacent to the highly doped semiconductor material, said lower doped layer having an unpinned surface potential and an electron affinity; and

a Schottky metal layer on said lower doped semiconductor material, said Schottky metal having a work function, said lower doped semiconductor material forming a junction with said Schottky metal having a barrier potential energy level that is dependent upon the type of Schottky metal, said barrier potential being approximately equal to said work function minus said electron affinity, said barrier potential being of a magnitude that allows said diode to operate as a low forward voltage (V_f) diode.

19. (Amended) The diode of claim 15, wherein [said Schottky metal contact has a work function,] said barrier potential [having] has an energy level that [varies directly with the] depends directly on said work function of said Schottky metal.

20. (Amended) The diode of claim [15] 18, further comprising a substrate adjacent to said n+ doped GaN layer, opposite said n- doped GaN layer.

22. (Amended) The diode of claim 15, wherein said Schottky metal is one of the metals in the group comprising [Ti,] Cr, Nb, Sn, W[, Ge] and Ta.

43. (Amended) A Group III nitride based Schottky diode, comprising:

a Group III nitride based semiconductor material having an unpinned surface potential; and

a Schottky metal having a work function and forming a junction with said semiconductor material that has a barrier potential, the height of said barrier potential depending upon said work function, said diode operating as a low forward voltage diode.

47. (Amended) The diode of claim 43, wherein the height of said barrier potential [varies positively with the] which depends positively on said work function of said Schottky metal.

48. (Amended) The diode of claim 45, further comprising a substrate made of sapphire (Al_2O_3), silicon carbide (SiC) or silicon (Si), adjacent to [the] said n+ GaN layer, opposite said n- GaN layer.

49. (Amended) The diode of claim 43, wherein said Schottky metal is one of the metals in the group comprising [Ti,] Cr, Nb, Sn, W, Ta[, Ge] and other metals with similar work functions.